

Magnetoelectric effect in composite structures based on piezoelectric single crystals

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The magnetoelectric (ME) effect is defined as coupling between polarization and magnetic fields (direct effect) and conversely between magnetization and electric fields (converse effect) in a matter. This effect has been of immense interest in the scientific community over the past few years. Unlike the ME single-phase multiferroics, numerous ME composites, combining elastically coupled piezoelectric (PE) and magnetostrictive (MS) phases, have been shown to yield very strong ME effects even at room temperature [1–3]. These structures also offer a great flexibility in the sense that a large number of parameters may be tuned independently including the material properties of the constituent phases as well as the connectivity between them. Consequently, nowadays these materials are already very close to some promising applications which include: DC and AC magnetic vector field sensors and electric current sensors, magneto-electro-elastic energy harvesters, multiple-state memory devices, micro-sensors in read heads, transformers, spinners, diodes, spin-wave generators and electrically tunable microwave devices.

In this work we have studied a variety of different magnetoelectric laminates by bonding magnetostrictive metglas foils onto single-crystalline substrates of LiNbO₃ (LNO), GaPO₄ (GPO) and PMN-PT. The measurements have been performed as a function of the crystal cut, magnitude and orientation of the magnetic bias field and the frequency of the modulation field [4]. Despite much weaker PE coefficients of LNO and GPO, direct ME effects have been found to have comparative magnitudes as compared to PMN-PT. Greatly enhanced ME coefficients in certain resonance modes are explored and their relations to the material properties of the crystals and the geometry of the composites are investigated. We demonstrate that control of the PE crystal's orientation can be used in order to obtain almost any desired quasi-static and resonant anisotropic ME properties for some given application. The anisotropic quasistatic ME coupling was generally found to be two times larger in the bidomain LNO samples stronger to their monodomain counterparts [5]. Large ME effects were obtained in low-frequency electromechanical resonance modes of the piezoelectric crystals. Of note is the fact that the contour modes were suppressed in the bidomain systems, whereas the bending modes were greatly enhanced. At a bending resonance frequency of 6862 Hz, we found a giant $|\alpha_{E31}|$ value up to $1704 \text{ V} \cdot (\text{cm} \cdot \text{Oe})^{-1}$ in laminate composite metglas / bidomain $\gamma+140^\circ$ -cut lithium niobate. Furthermore, the equivalent magnetic noise spectral density of the investigated composite material was only $92 \text{ fT/Hz}^{1/2}$, a record value for such a low operation frequency [6]. Thus, we have shown that such systems may be used in simple and sensitive low-frequency magnetic and current sensors.

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